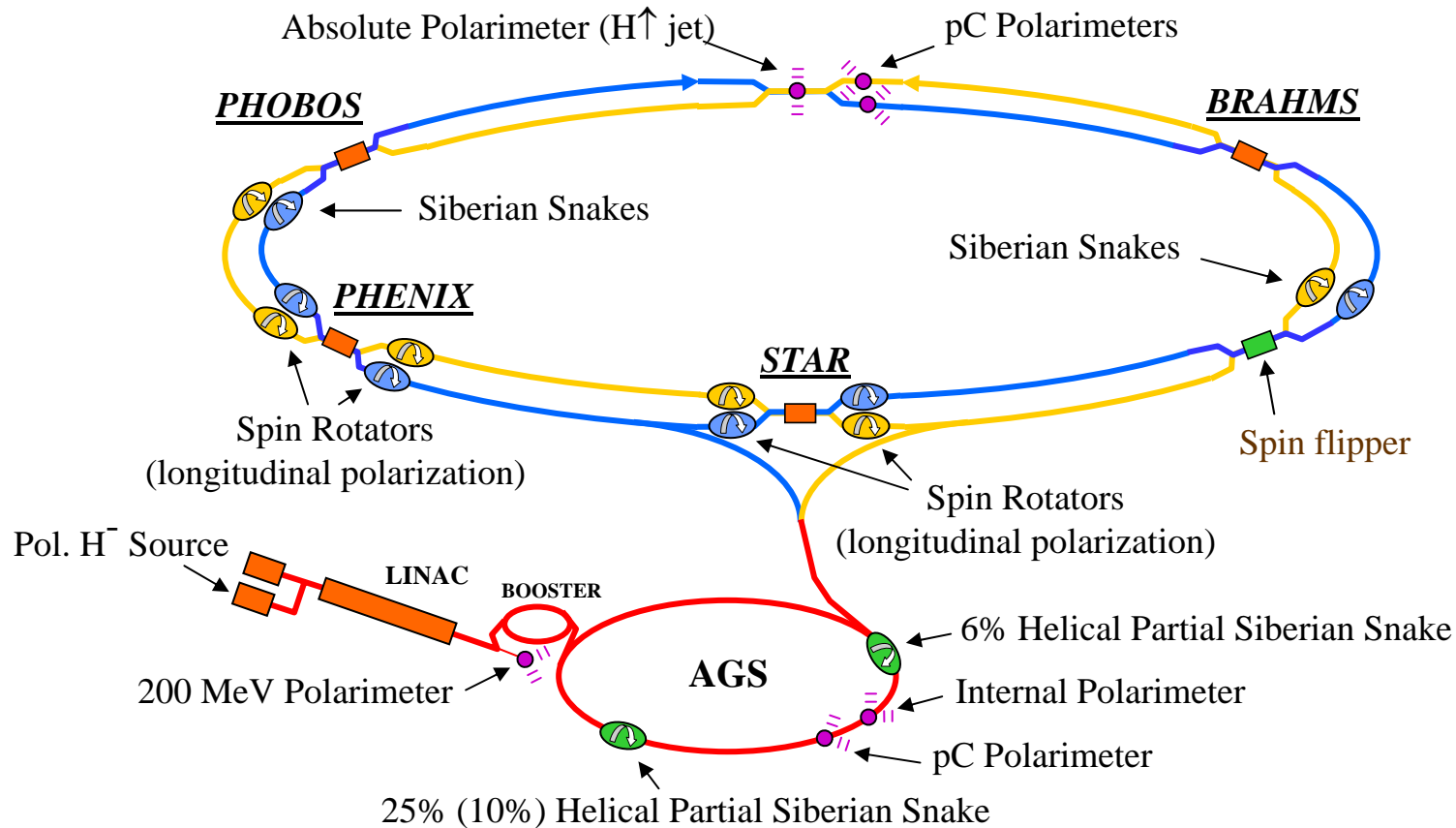# RHIC Polarized Protons Operations and Plans

Run-6 luminosity and polarization performance

Towards RHIC Spin plan performance

BROOKHAVEN
NATIONAL LABORATORY

Thomas Roser
DOE NP S&T review
July 24, 2006

RHIC – first polarized hadron collider

Absolute Polarimeter (H↑ jet)

pC Polarimeters

PHOBOS

BRAHMS

Siberian Snakes

Siberian Snakes

PHENIX

STAR

Spin Rotators
(longitudinal polarization)

Spin flipper

Spin Rotators
(longitudinal polarization)

Pol. H⁻ Source

LINAC

BOOSTER

6% Helical Partial Siberian Snake

AGS

Internal Polarimeter

200 MeV Polarimeter

pC Polarimeter

25% (10%) Helical Partial Siberian Snake

Without Siberian snakes: $\nu_{sp} = G\gamma = 1.79$ E/m $\rightarrow$ ~1000 depolarizing resonances
With Siberian snakes (local 180° spin rotators): $\nu_{sp} = \frac{1}{2} \rightarrow$ no first order resonances

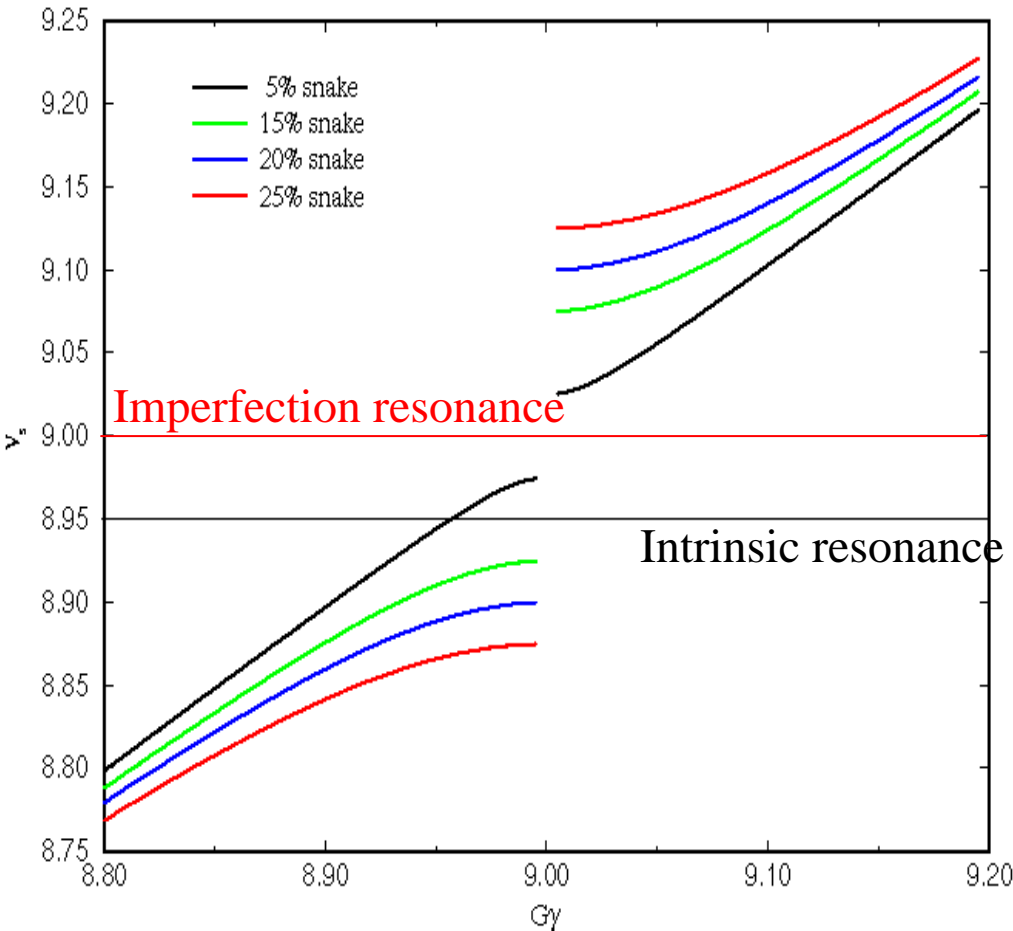**BROOKHAVEN**
NATIONAL LABORATORY

Luminosity and polarization
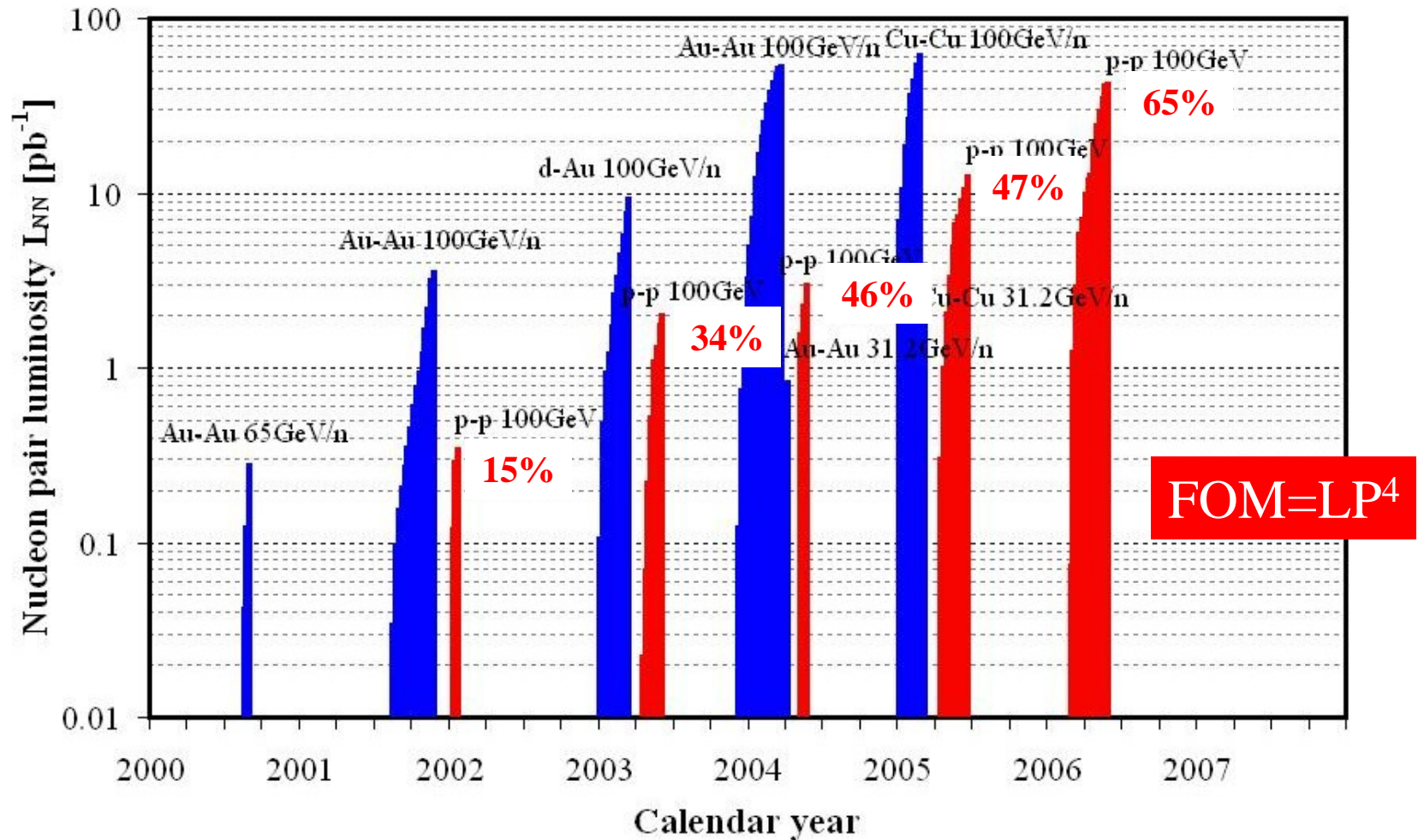
Major improvements: Cold AGS snake: 65% polarization at 1.5×10^{11} proton / bunch
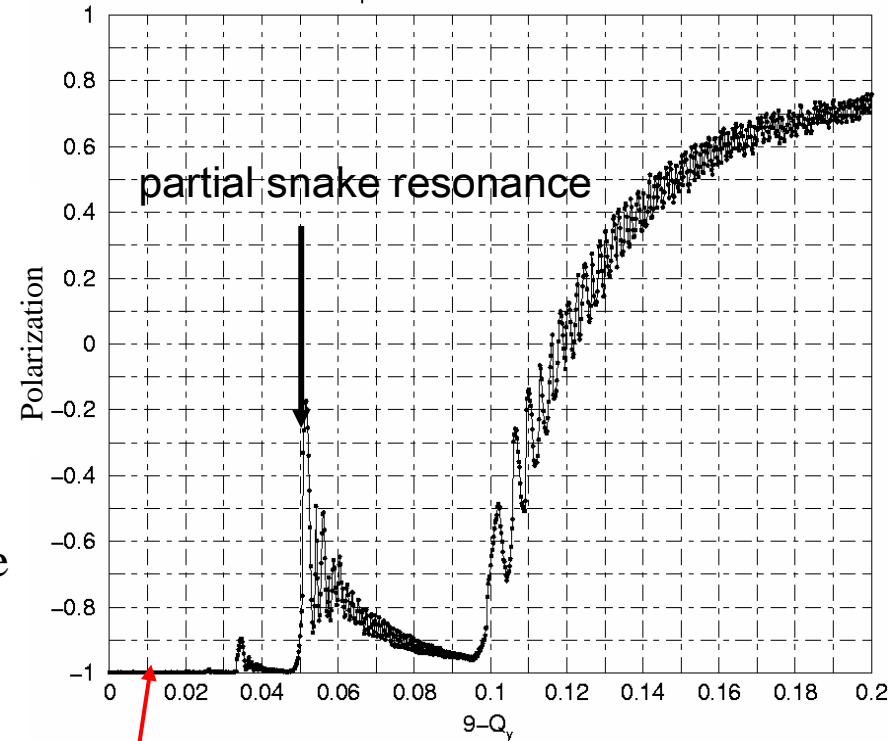**Little pressure rise in RHIC with NEG coated vacuum pipes**

Strong Partial Siberian Snake in AGS

Spin Tune for a partial snake

- — 5% snake
- — 15% snake
- — 20% snake
- — 25% snake

Imperfection resonance

Intrinsic resonance

$$\cos(180^\circ \, \nu_{sp}) = \cos(\delta/2) \cdot \cos(180^\circ \, G\gamma)$$

$G\gamma = 36 + \nu, \; \varepsilon = 0.011$

64 ptrs w. $10 \, \pi$ mm–mrad emittance

partial snake resonance

desired vertical betatron tune to avoid depolarization

Challenges:
1. SC element in warm machine
2. Lattice disturbances

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New AGS helical snakes

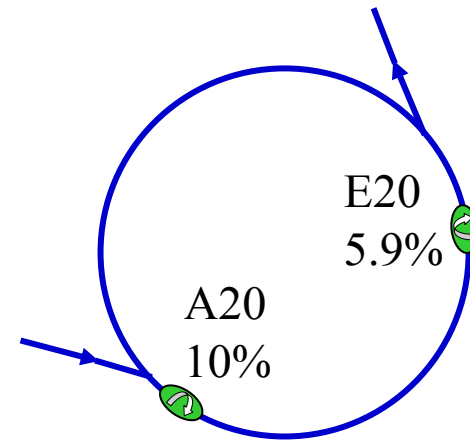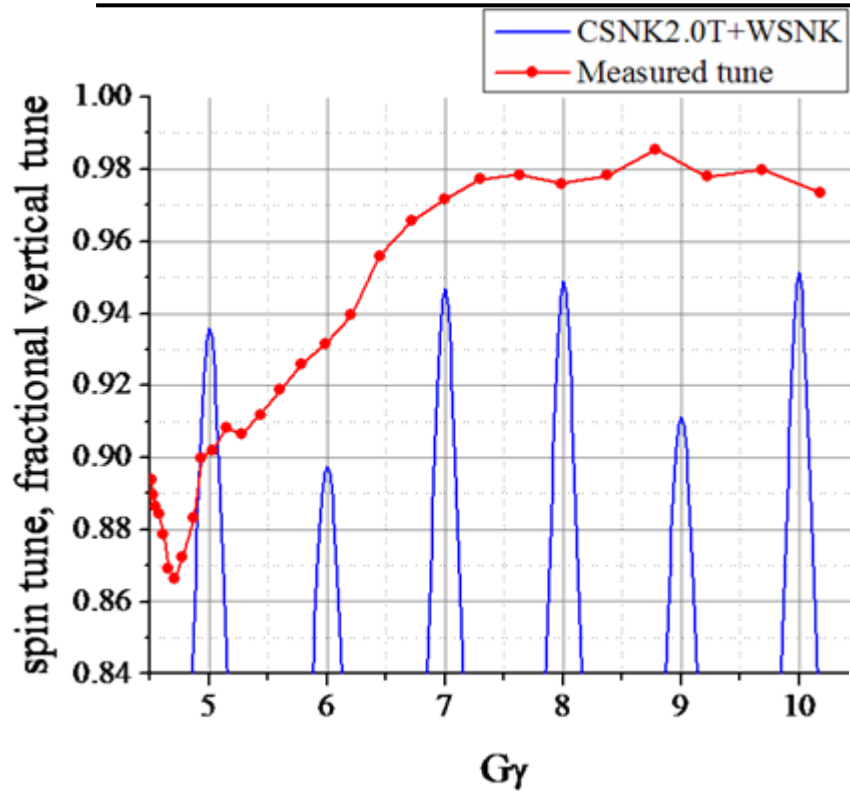6 % helical snake build at Tokana Industries funded by RIKEN.

2.6 m

> Warm snake avoids polarization mismatch at AGS injection and extraction.
> Cold strong snake eliminates all depolarizing resonances in AGS.

2.6 m
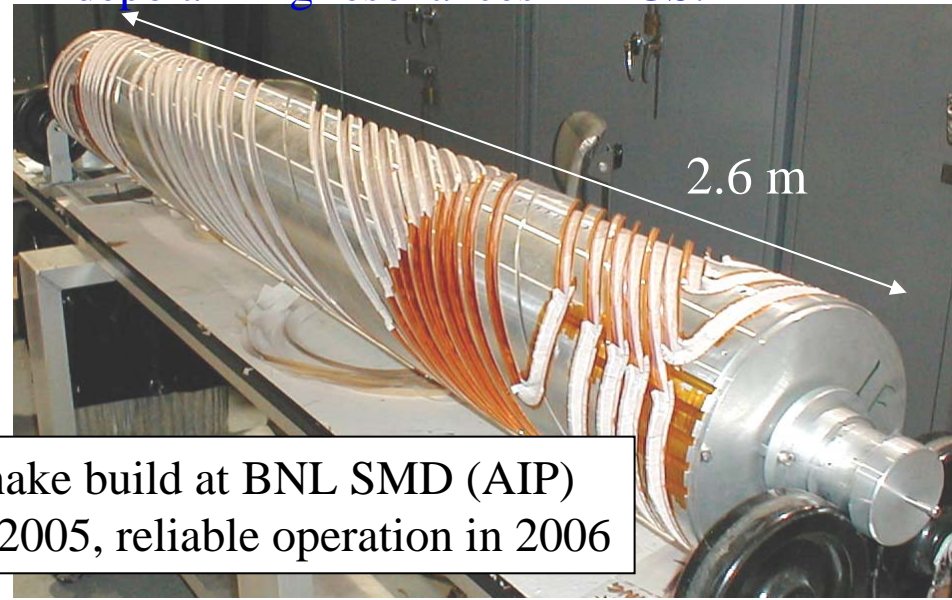
25% s.c. helical snake build at BNL SMD (AIP) Commissioned in 2005, reliable operation in 2006

Two snakes in AGS

- Two snakes give larger spin tune gap
- AGS stable with $Q_y = 8.98$!
- Ramp measurement with AGS pC CNI polarimeter shows no obvious residual depolarization
- With strong partial snakes weak depolarization from horizontal intrinsic resonances
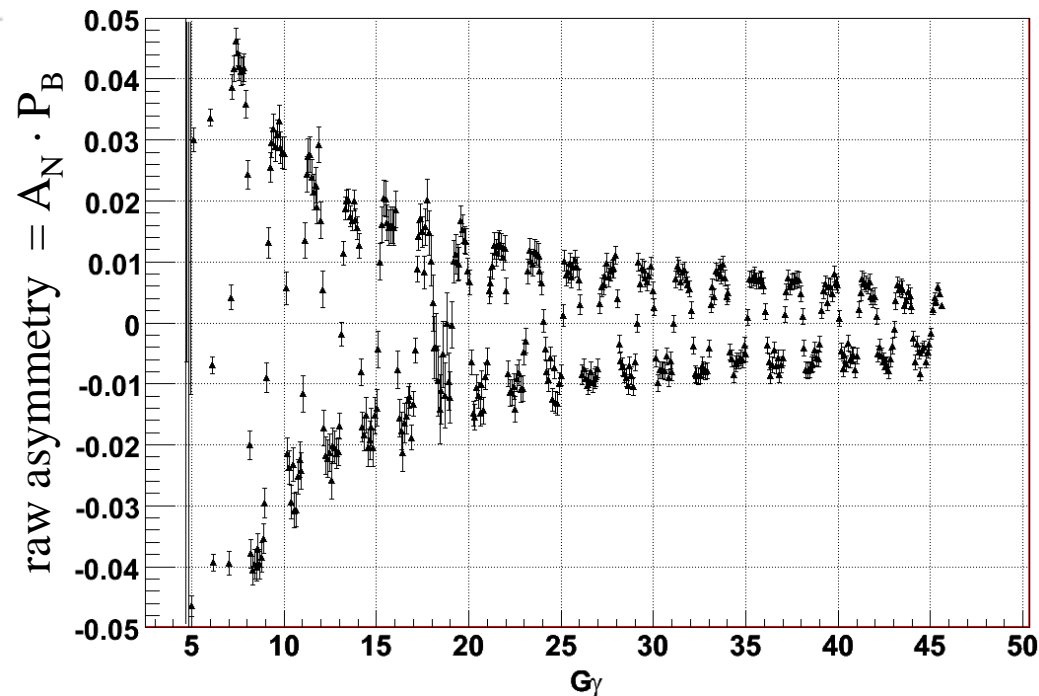
Results of AGS polarization development

- 65% polarization and 1.5×10^{11} protons/bunch with two partial snakes in the AGS. [2002: 30% 0.7×10^{11} ; 2003: 40% 0.7×10^{11} ; 2004: 50% 0.7×10^{11} ; 2005: 50% 1.1×10^{11}]

- Snake setup with best polarization: 10% cold snake, 5.9% warm snake.

- Four compensation quads around warm snake improved dynamic aperture

- Little intensity dependence of polarization with this setup.

- Remaining polarization loss:
  - ~ 10% due to vertical (~5%) and horizontal (~5%) intrinsic resonances
  - ~ 1% due to injection and extraction mismatch
  - ~ 10% polarization loss unexplained.

- For next year:
  - upgrade AGS quadrupoles to move horizontal tune also into spin tune gap
  - minimize space charge emittance growth at AGS injection: less polarization loss from intrinsic resonances
  - improve polarimeter calibration and polarization ramp measurement to identify and confirm residual polarization loss.
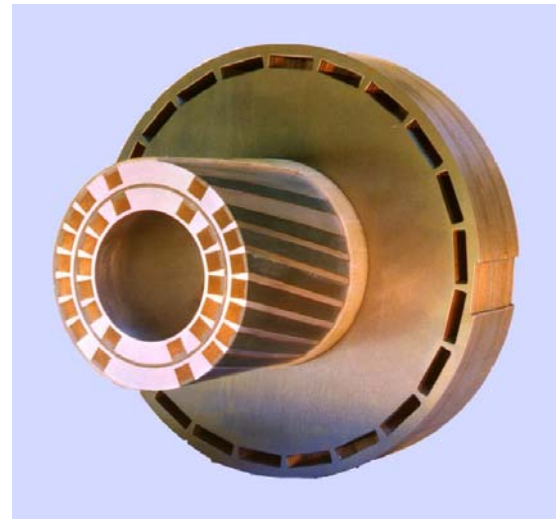
Siberian Snake in RHIC Tunnel

Siberian Snake: 4 superconducting helical dipoles, 4Tesla,
2.4 m long with full 360° twist
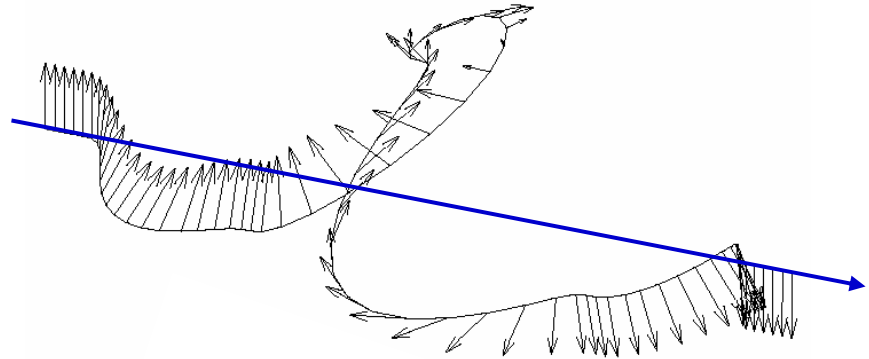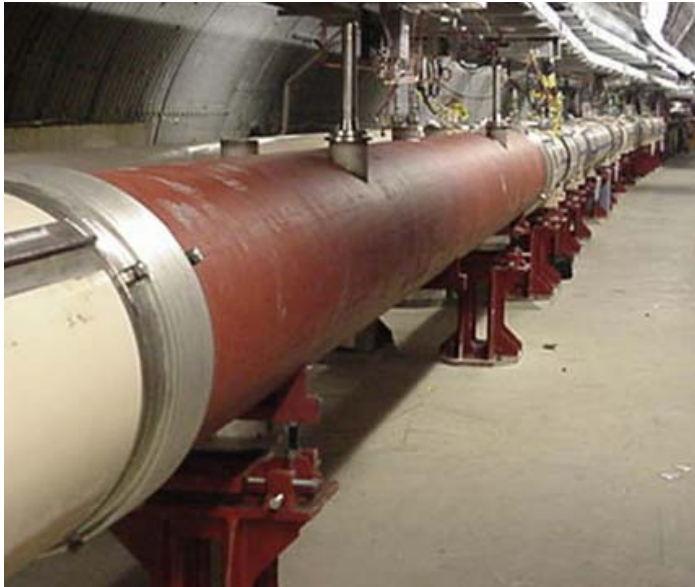
Funded by RIKEN, Japan
Designed and constructed at BNL

Run-6 polarized proton runs

| Beam energy	100 GeV	11 GeV	31.2 GeV	250 GeV
Purpose	Physics operation	Machine test	Physics operation	Machine test
Time	12 weeks	1 day	2 weeks	1 week
Participating experiments	PHENIX STAR		PHENIX STAR BRAHMS	
Run coordinator	Vadim Ptitsyn	Todd Satogata	Vadim Ptitsyn	Mei Bai

Run-6 100 x 100 GeV Integrated luminosity

Run6 100 x 100 GeV pp Integrated Luminosity (Final Delivered) for Physics

Integrated luminosity by week
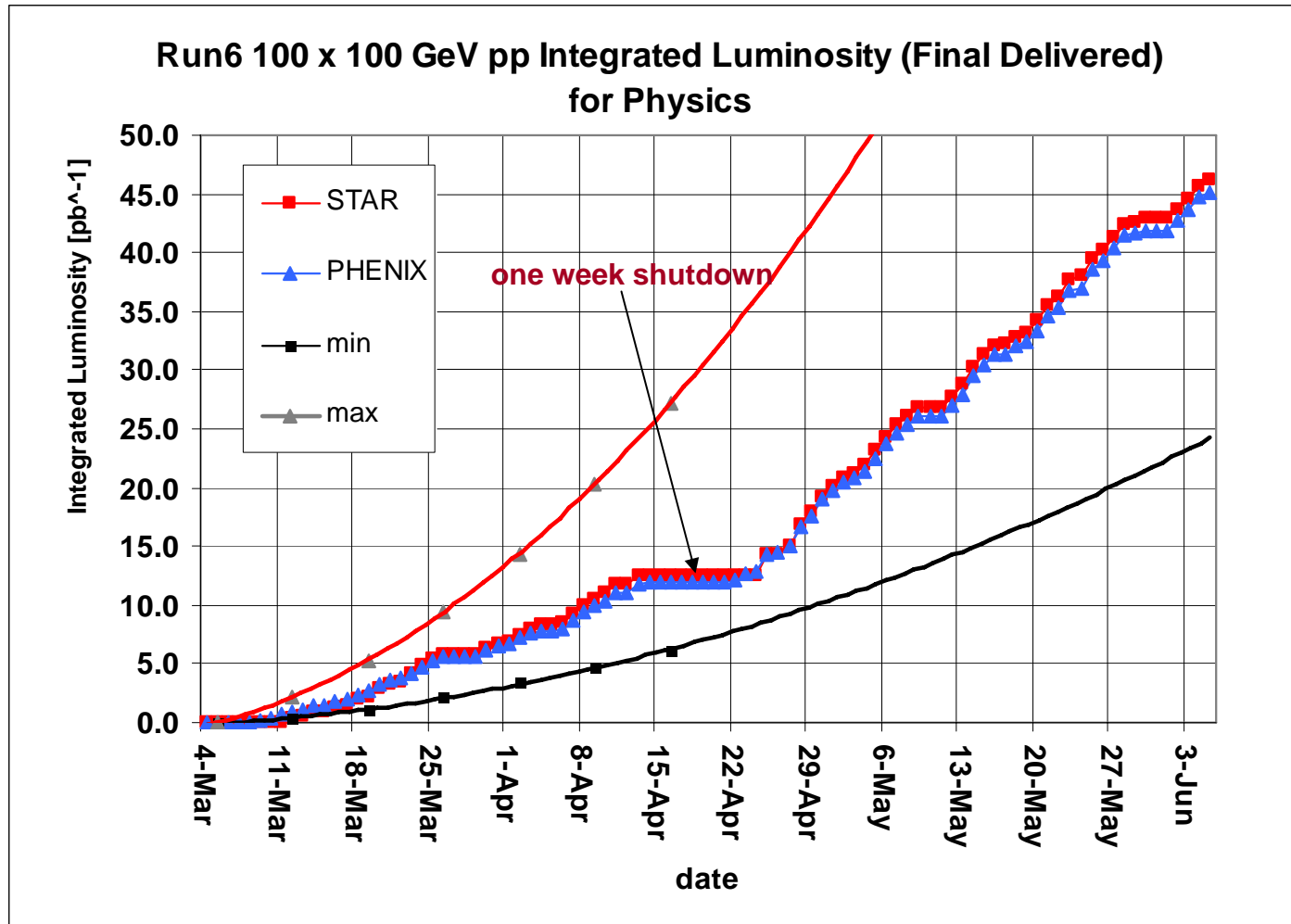
Run 6 (p^p^) -- Integrated Luminosity by week
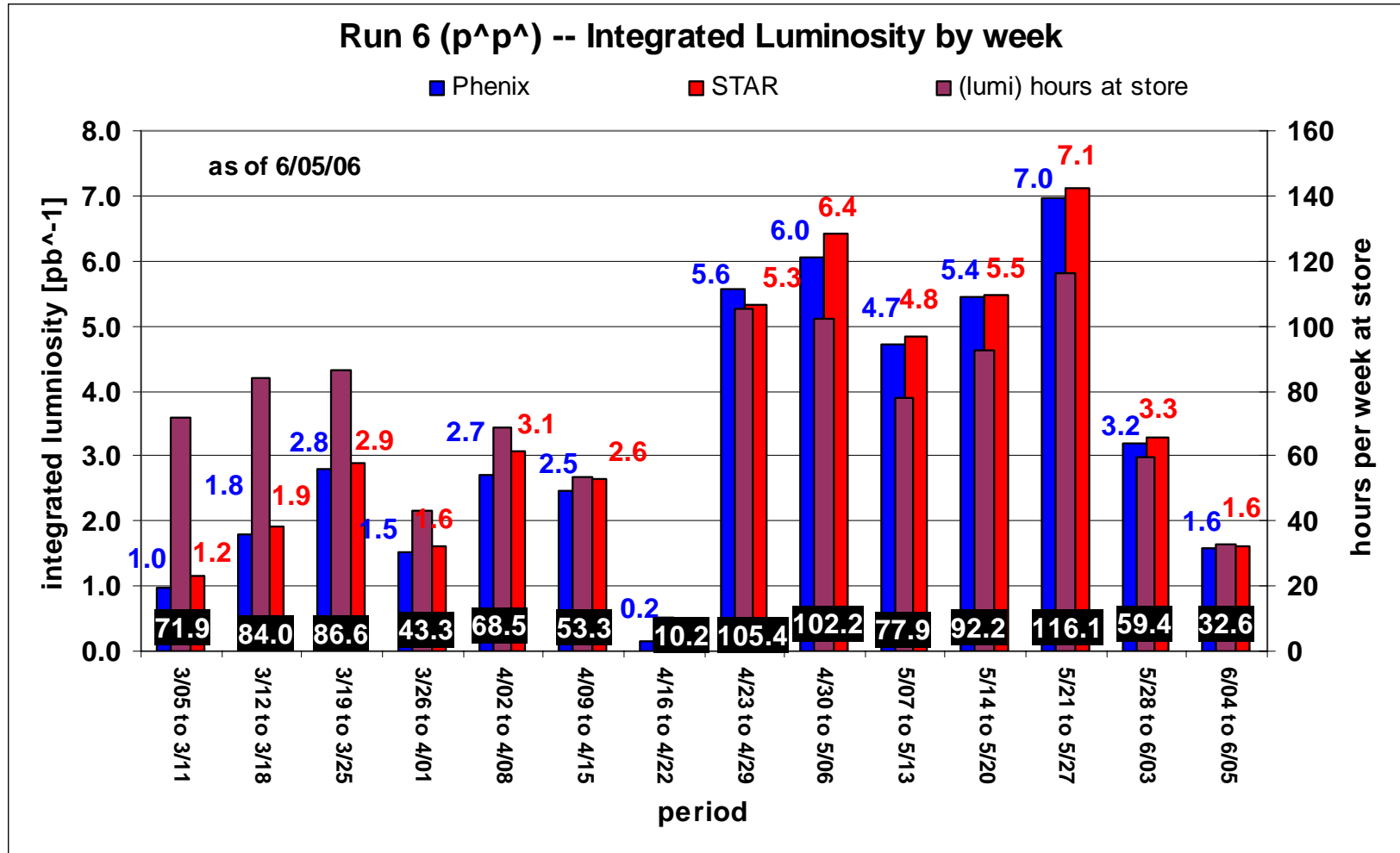
% Calendar time in store after setup
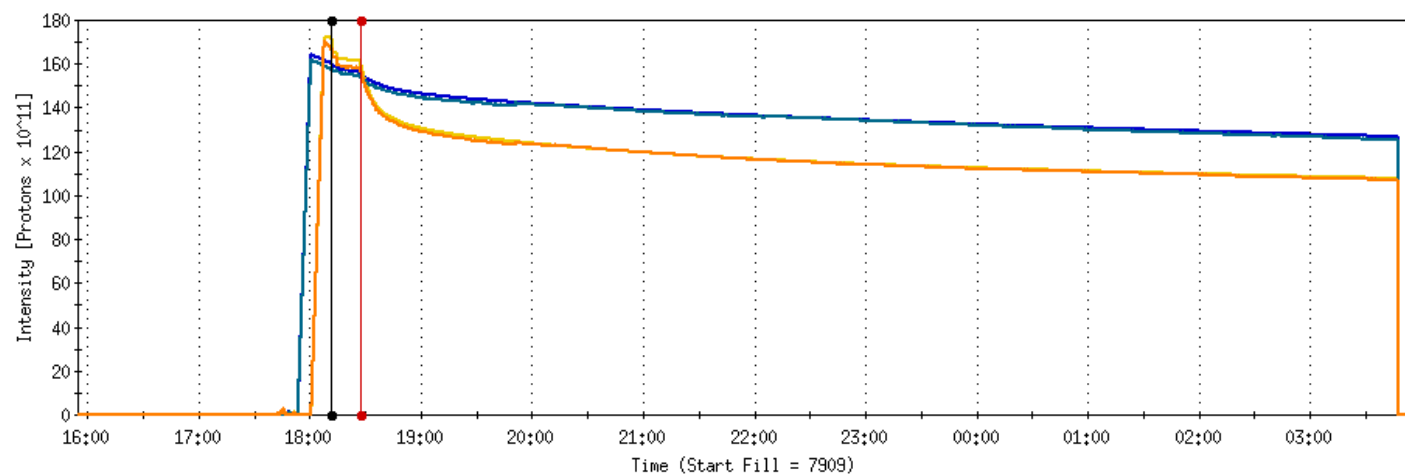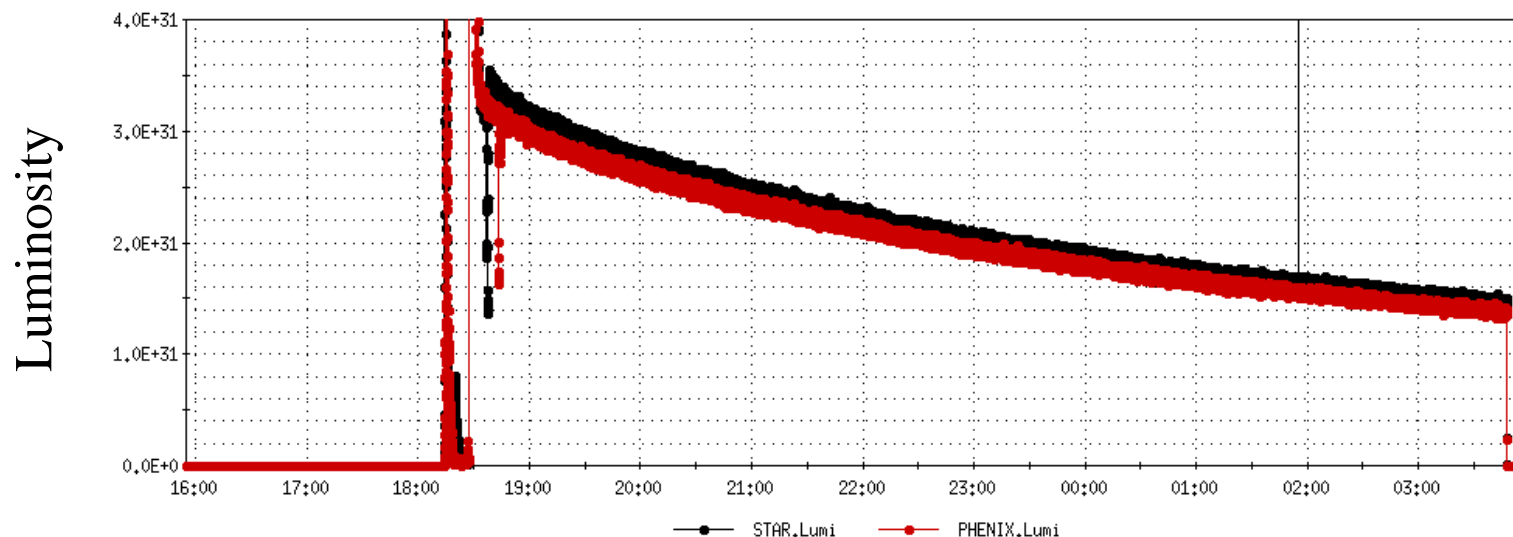

goal
100h/week
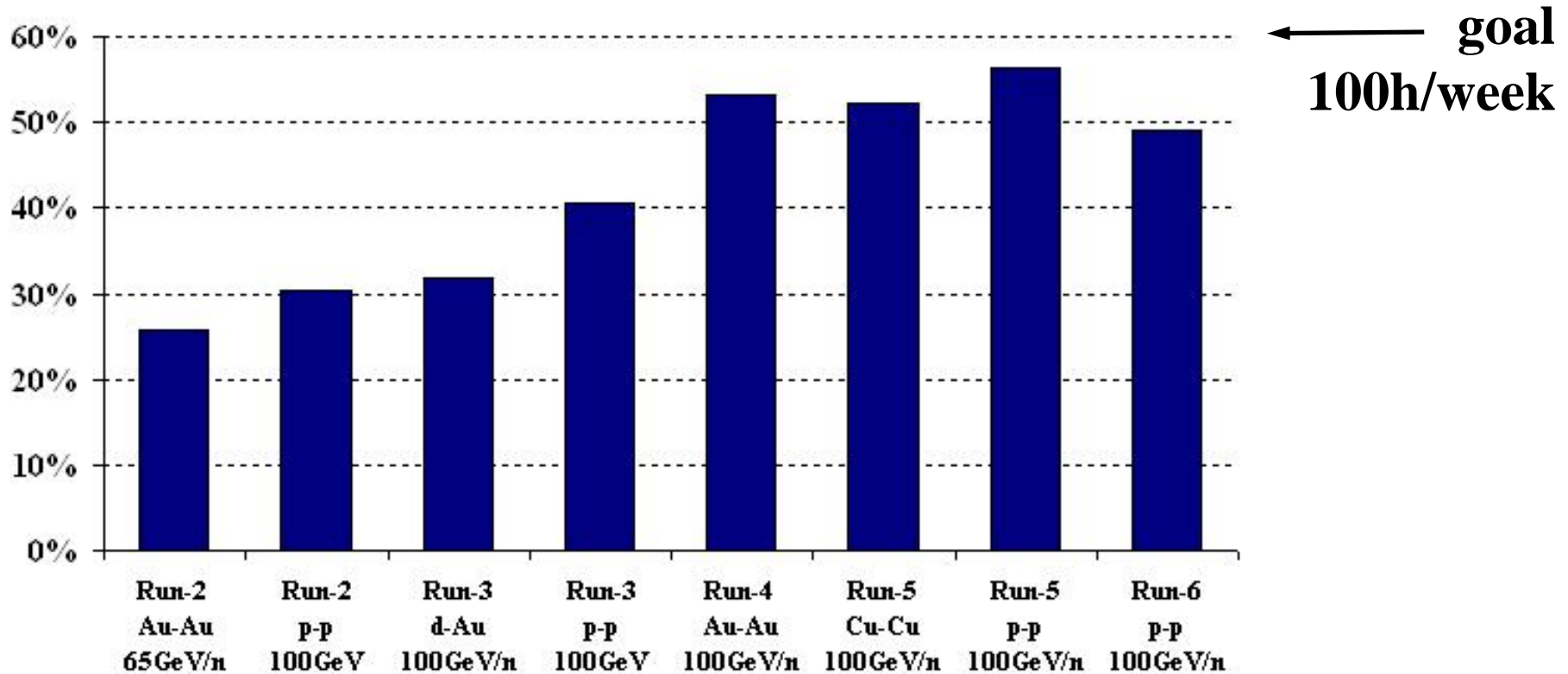
Rest of the time:

~20% machine tuning/ramping

~15% failures

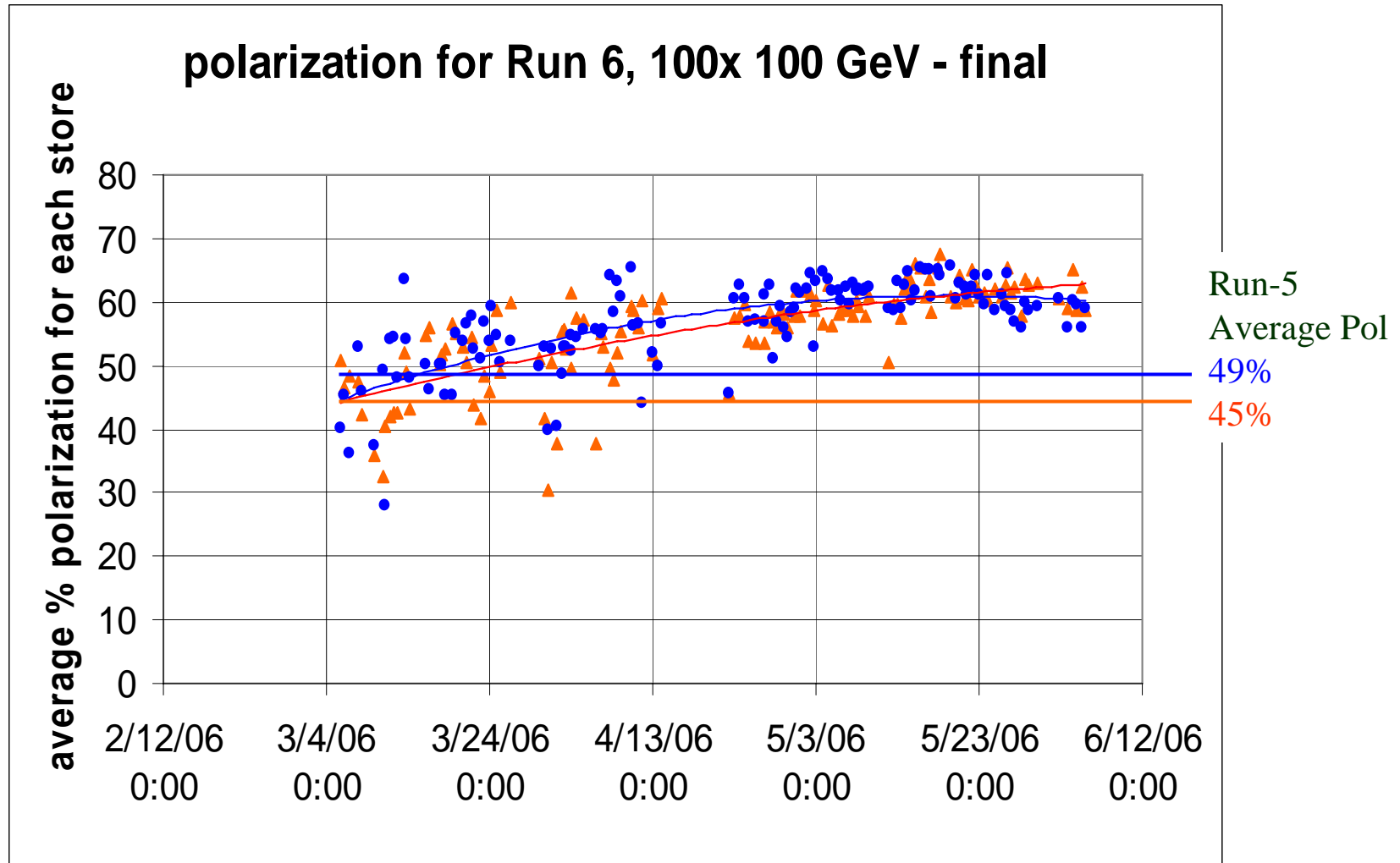~10% machine development and accelerator physics experiments

~ 5% maintenance and access
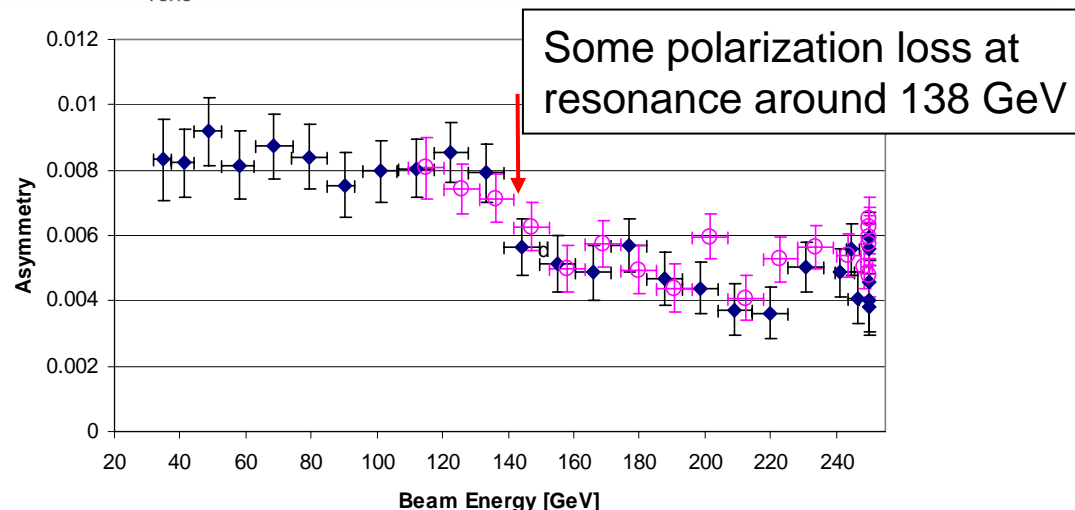
Golden store #7909

Polarization at 100 GeV

polarization for Run 6, 100x 100 GeV - final

Polarized protons performance at 100 GeV

Parameter	Unit	2002	2003	2004	2005	2006
No. of bunches	--	55	55	56	106	**111**
bunch intensity	10^{11}	0.7	0.7	0.7	0.9	**1.3**
store energy	GeV	100	100	100	100	**100**
β^*	m	3	1	1	1	**1**
peak luminosity	$10^{30}\text{cm}^{-2}\text{s}^{-1}$	2	6	6	10	**35**
average luminosity	$10^{30}\text{cm}^{-2}\text{s}^{-1}$	1	4	4	6	**20**
Collision points	--	4	4	4	3	**2**
average polarization, store	%	15	35	46	47	**60-65%**

250 GeV development

- Achieved at least 45% polarization at 250 GeV (using 100 GeV analyzing power)
- No beam loss on ramp
- Some polarization loss on ramp

Polarization at injection

~ 45%

Preliminary online data
100 GeV analyzing power

Some polarization loss at resonance around 138 GeV
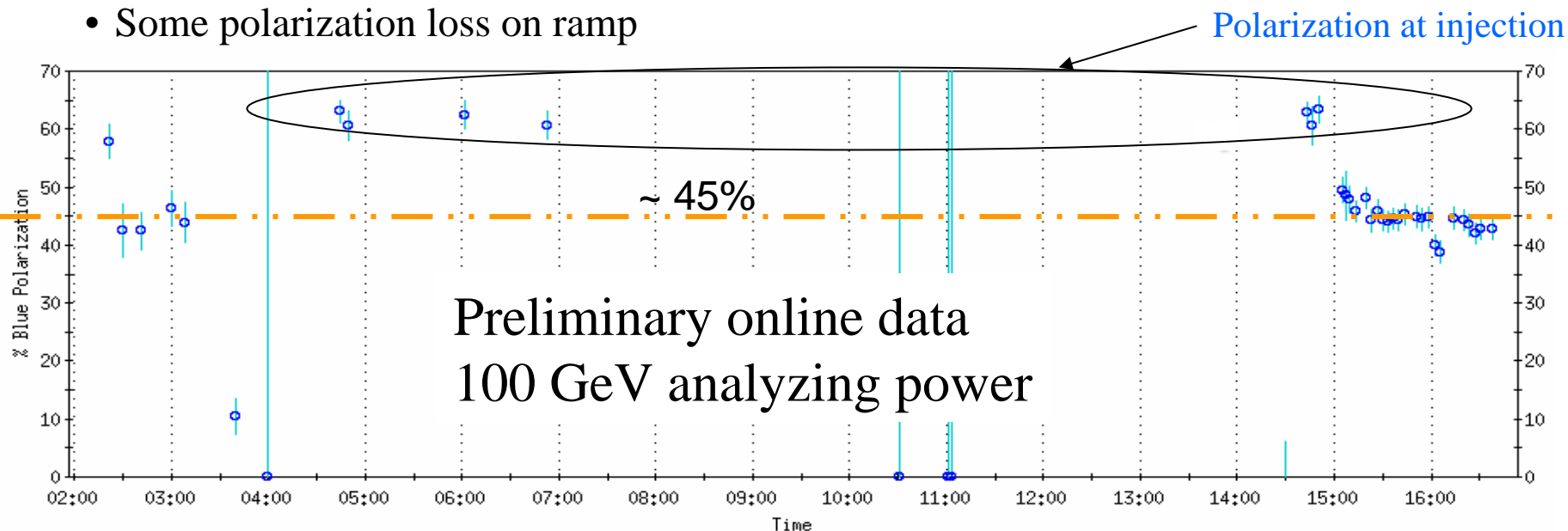
Towards "Enhanced Luminosity" (Midterm/spin plan)

100 x 100 GeV until 2008:

Goal: $\langle L \rangle = 60 \times 10^{30}$ cm^{-2} s^{-1} (3 x achieved)

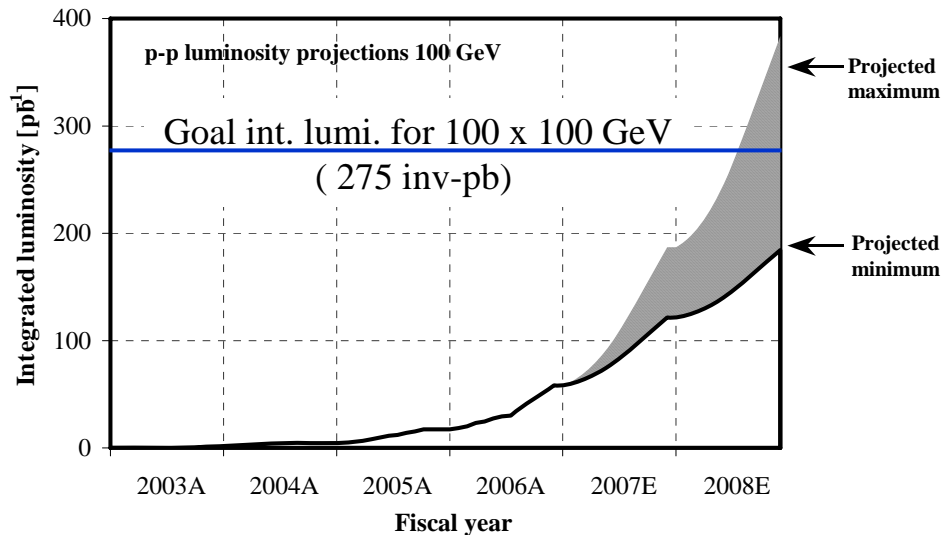70 % polarization; 100hrs/week at store

"Enhanced RHIC Task Force"

Need 10 weeks pp / year to reach goal!

250 x 250 GeV: Start physics in 2009

Machine development in 2007 and 2008

Goal: $\langle L \rangle = 150 \times 10^{30}$ cm^{-2} s^{-1}

p-p luminosity projections 100 GeV

Goal int. lumi. for 100 x 100 GeV (275 inv-pb)

Projected maximum

Projected minimum

Fiscal year		2002A	2003A	2004A	2005A	2006A	2007E	2008E
No of bunches	…	55	55	56	106	111	111	111
Ions/bunch, initial	10^{11}	0.7	0.7	0.7	0.9	1.3	1.8	2.0
Average beam current/ring	mA	48	48	52	119	187	243	280
β^*	m	3	1	1	1	1	1	0.9
Peak luminosity	10^{30} cm^{-2}s^{-1}	2	6	6	10	35	61	90
Average store luminosity	10^{30} cm^{-2}s^{-1}	1.5	3	4	6	20	41	60
Time in store	%	30	41	41	56	49	58	60
Maximum luminosity/week	pb^{-1}	0.2	0.6	0.9	1.9	7.0	14.3	21.9
Minimum luminosity/week	pb^{-1}						7.0	7.0
Maximum integrated luminosity	pb^{-1}	0.5	1.6	3	13	45	123	180
Minimum integrated luminosity	pb^{-1}						63	63
AGS polarization at extraction	%	35	45	50	55	65	70	80
RHIC store polarization, average	%	15	35	46	47	65	65	70
Maximum LP[4]/week	nb^{-1}	0	9	40	90	1250	2550	5250
Minimum LP[4]/week	nb^{-1}						1250	1250

Luminosity limit: beam-beam for p↑- p↑

intensities

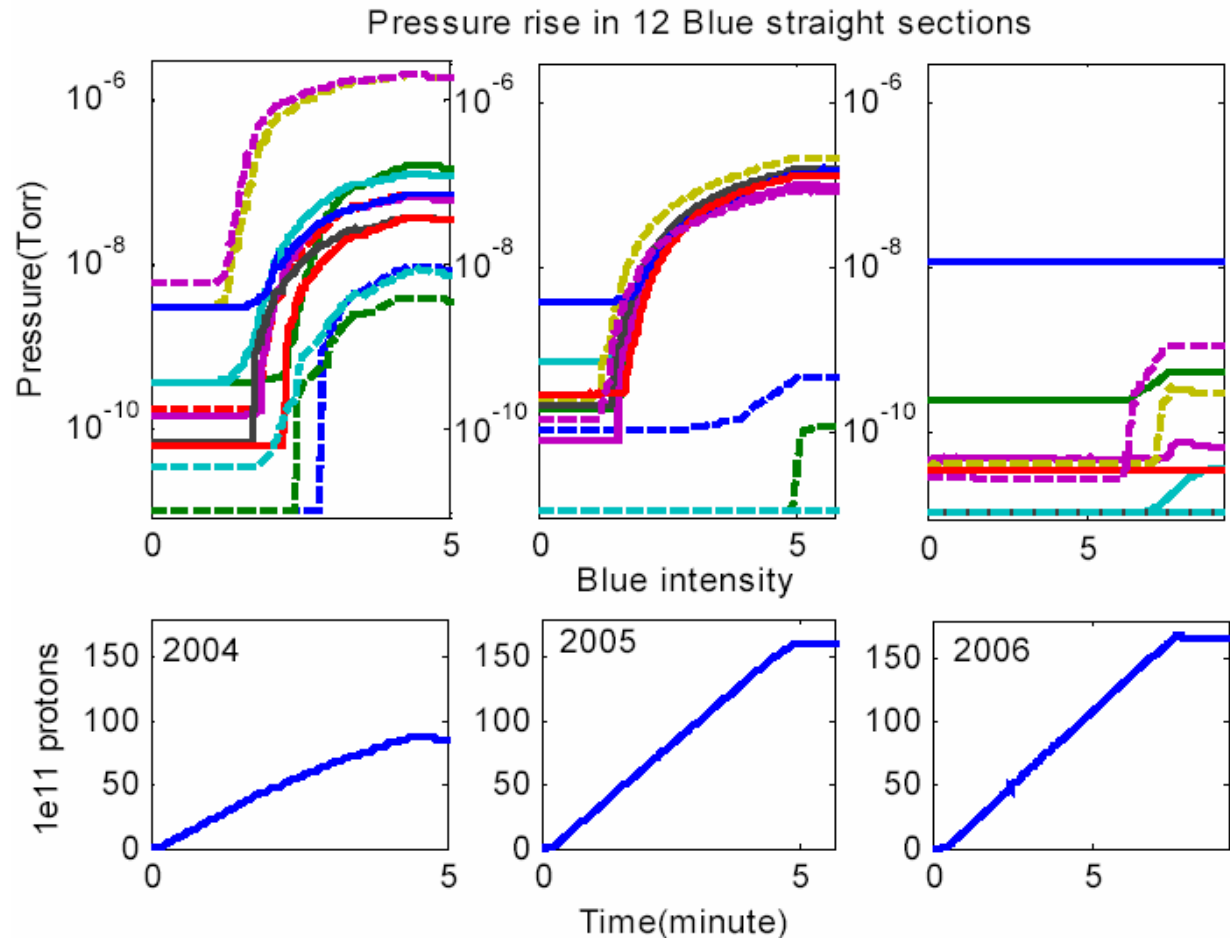**luminosity**

$Q_y - 29$

$Q_x - 28$

7/10

13th

2/3

2/3   7/10
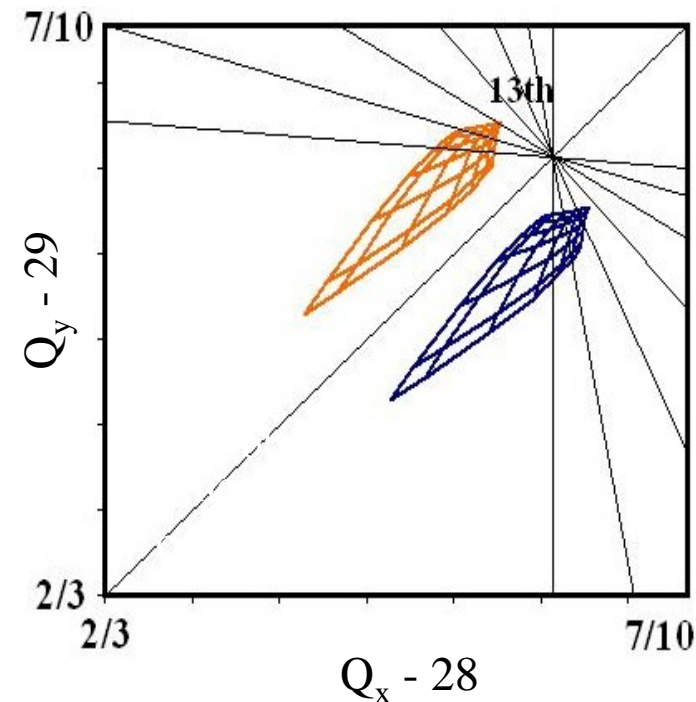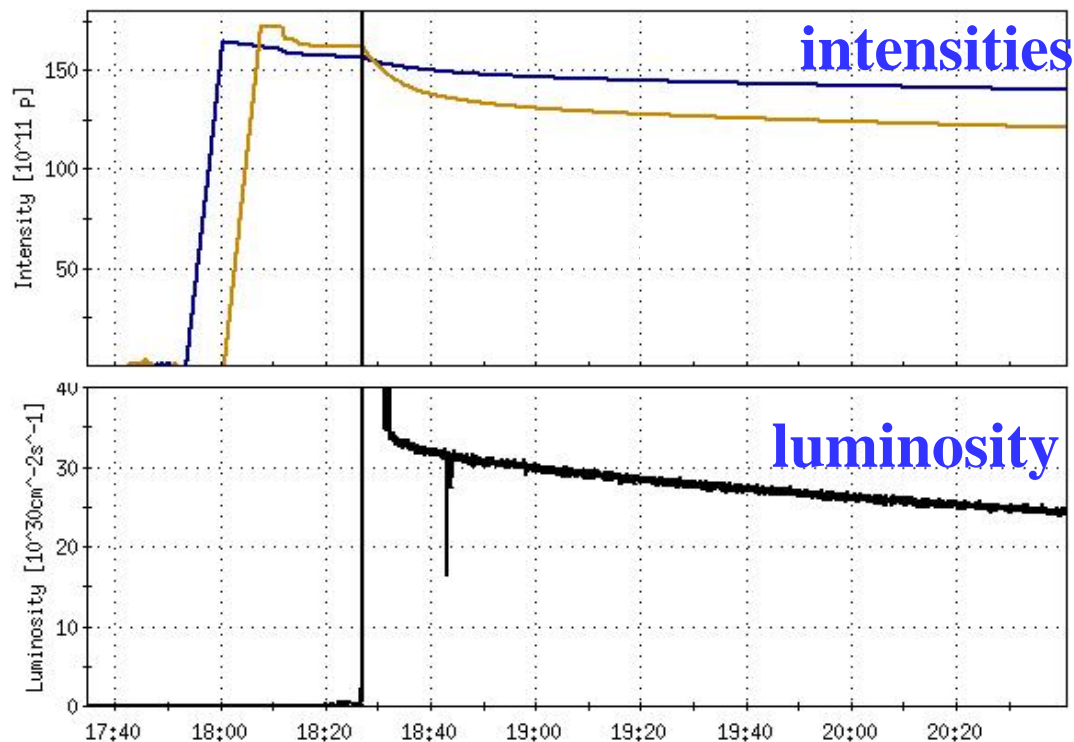
- Total beam-beam induced tune spread reached $\Delta Q_{bb,tot} = 0.012$
- Other sources of tune spread: $\Delta Q \approx 0.005$
  - nonlinear chromaticity (correction planned for Run-7)
  - triplet errors (locally corrected)
  - electron cloud?
- New working point close to integer?

Luminosity Limit – Dynamic Pressure Rises

- All operational relevant pressure rises can be explained by electron clouds
- Installation of NEG (non-evaporative getter) coated beam pipes dramatically improved beam intensity limit
- Already tested goal intensity of 111 bunches with 2×10^{11} proton / bunch

Pressure rise in 12 Blue straight sections

Summary

Very successful Run-6 polarized proton run:

- Luminosity increased 3 times
- New record polarization of 65%
- First polarized beam at 250 GeV; > 45% polarization

Planned for next 2 years :

- Another factor of 3 increase in luminosity
- Increase polarization from 65% to 70 %

Start operation at 250 x 250 GeV in 2009

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